PROGRESS REPORT FORM DOE ARM July 2000

A Coordinated Effort to Improve Parameterization of High-Latitude Cloud and Radiation Processes

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Scientific Goals:

In support of the Atmospheric Radiation Measurement (ARM) Program's effort to improve the treatment of radiation and clouds in models used to predict future climate, a renewal proposal is submitted to extend an ongoing study to improve our capability of modeling key processes related to clouds and radiation in the Arctic. This study is of particular relevance to ARM's proposed North Slope of Alaska sites. Our proposed activities will include the following elements:

- analysis and "scientific" quality control of data obtained at NSA/AAO sites
- design and proposal of, and participation in intensive operational periods (IOPs) at NSA/AAO sites
- preparation of case studies suitable for SCM and CRMs from NSA/AAO data for GCSS Working Group on Polar Clouds projects
- use of NSA/AAO data to force, evaluate, and improve the treatment of cloud and radiation processes in cloud resolving models, single column models, and the Arctic Regional Climate System Model
- development and application of a method based upon feedback control theory to use the time series data to evaluate single-column model simulations
- use of observations and models to address the site specific science questions in Chapter 9 (NSA/AAO) of the ARM Science Plan
- promotion of linkages of ARM NSA/AAO activities with NSF and NASA projects in the Arctic.

Research highlights:

- Evaluation of different snow/ice surface albedo parameterizations used in climate models against SHEBA data. Evaluation included comparison of the performance of different albedo parameterizations in simulations with a single-column ice thickness distribution model. Perturbed simulations were performed using the different surface albedo parameterizations This constitutes the first example (that I know of) of using feedback analysis to evaluate different parameterizations. While two of the surface albedo parameterizations produced the same annually averaged surface albedo, the two parameterizations had very different feedback gain ratios, owing to the different number and types of degrees of freedom in the parameterization (Curry et al. 2000b)

- Assembly of 4 case studies from SHEBA for which radiation flux closure experiments were conducted. The SHDOM model was used in the calculations, where the code was modified to use RRTM k-distribution and include ice crystal single scattering properties. The calculations show that the model-derived surface radiation fluxes are within 5% of observed fluxes; a more stringent challenge to evaluating the model requires improved analysis of the observed radiation fluxes and atmospheric aerosol properties. (Benner et al. 2000).

- Single column simulations of mixed phase and crystalline arctic clouds, and evaluation using SHEBA data. These simulations included both explicit microphysics (with resolved size distribution for both liquid and ice particles) and a bulk microphysics parameterization. A new bulk microphysics parameterization is developed that includes prognostic equations for ice and liquid water content, concentration of ice and liquid particles, and in-cloud supersaturation. The new bulk microphysics parameterization produces substantially improved simulations of mixed-phase clouds (Khvorostyanov and Curry 2000b; Girard and Curry 2000)

- Development of a new formulation of the theory of heterogeneous crystal nucleation in clouds by freezing. This theory unifies and explains two basic empirical laws of ice nuclei (IN) behavior: temperature and supersaturation dependence. The theory also explains observations of high nucleation rates and crystal concentrations at warm (-5 to -12°C) temperatures and high values of “ice multiplication factor” when splintering mechanism may be not effective. This theory can be applied to parameterizations for use in cloud and climate models (Khvorostyanov and Curry, 2000a).

Refereed publications since 1999, including updates to publications listed in last year's report (2 copies of each have been sent to P. Crowley):

Stamnes, K., Ellingson, R.G., J.A. Curry, J.E. Walsh, and B. D. Zak, 1999: Review of science issues and deployment strategies for the North Slope of Alaska/Adjacent Arctic Ocean (NSA/AAO) ARM site. *J. Climate*, 12, 46-63.

Pinto, J.O., J.A. Curry, and A.H. Lynch, 1999: Modeling clouds and radiation for the November 1997 period of SHEBA using a column climate model. *J. Geophys. Res*., 104, 6661-6678.

Khvorostyanov, V.I., and J.A. Curry, 1999a: A simple analytical model of aerosol properties with account for hygroscopic growth. Part I: Equilibrium size spectra and CCN activity spectra. *J. Geophys. Res*., 104, 2163-2174.

Khvorostyanov, V.I., and J.A. Curry, 1999b: A simple analytical model of aerosol properties with account for hygroscopic growth. Part II: Scattering and absorption coefficients. *J. Geophys. Res.*, 104, 2175-2184.

Khvorostyanov, V.I. and J.A. Curry, 1999c: Theory of Stochastic Condensation in Clouds. Part I: A General Kinetic Equation. *J. Atmos. Sci*, 56, 3985-3996.

Khvorostyanov, V.I. and J.A. Curry, 1999d: Theory of Stochastic Condensation in Clouds. Part II: Analytical Solutions of the Gamma-Distribution Type. *J. Atmos. Sci*, 56, 3997-4013.

Curry, J.A., P. Hobbs, M. King, D. Randall, P. Minnis, et al., 2000a: FIRE Arctic Clouds Experiment. *Bull. Amer. Meteorol. Soc*., 81, 5-30.

Khvorostyanov, V.I. and J.A. Curry, 2000a: A New Theory of Heterogeneous Ice Nucleation for Application in Cloud and Climate Models. *Geophys. Res. Lett*., submitted.

Curry, J.A., J.L. Schramm, D. Perovich, and J.O. Pinto, 2000b: Application of SHEBA/FIRE data to evaluation of sea ice surface albedo parameterizations. *J. Geophys. Res*., in press.

Benner, T., J.A. Curry, and J.O. Pinto, 2000: Radiative transfer in the summertime Arctic. *J. Geophys. Res.*, in press.

Girard, E. and J.A. Curry, 2000: Simulation of arctic low-level clouds observed during the FIRE Arctic Clouds Experiment using a new bulk microphysics scheme. *J. Geophys. Res*., in press.

Khvorostyanov, V.I., J.A. Curry, et al., 2000b: Evaluation of an explicit microphysics scheme using observations of an upper-level cloud system observed during FIRE.ACE. *J. Geophys. Res.*, in press.

Curry, J.A., 2000: Introduction to special section: FIRE Arctic Clouds Experiment. *J. Geophys. Res*., 105, submitted.